PGDP Probabilistic and Deterministic Seismic Hazard Analyses

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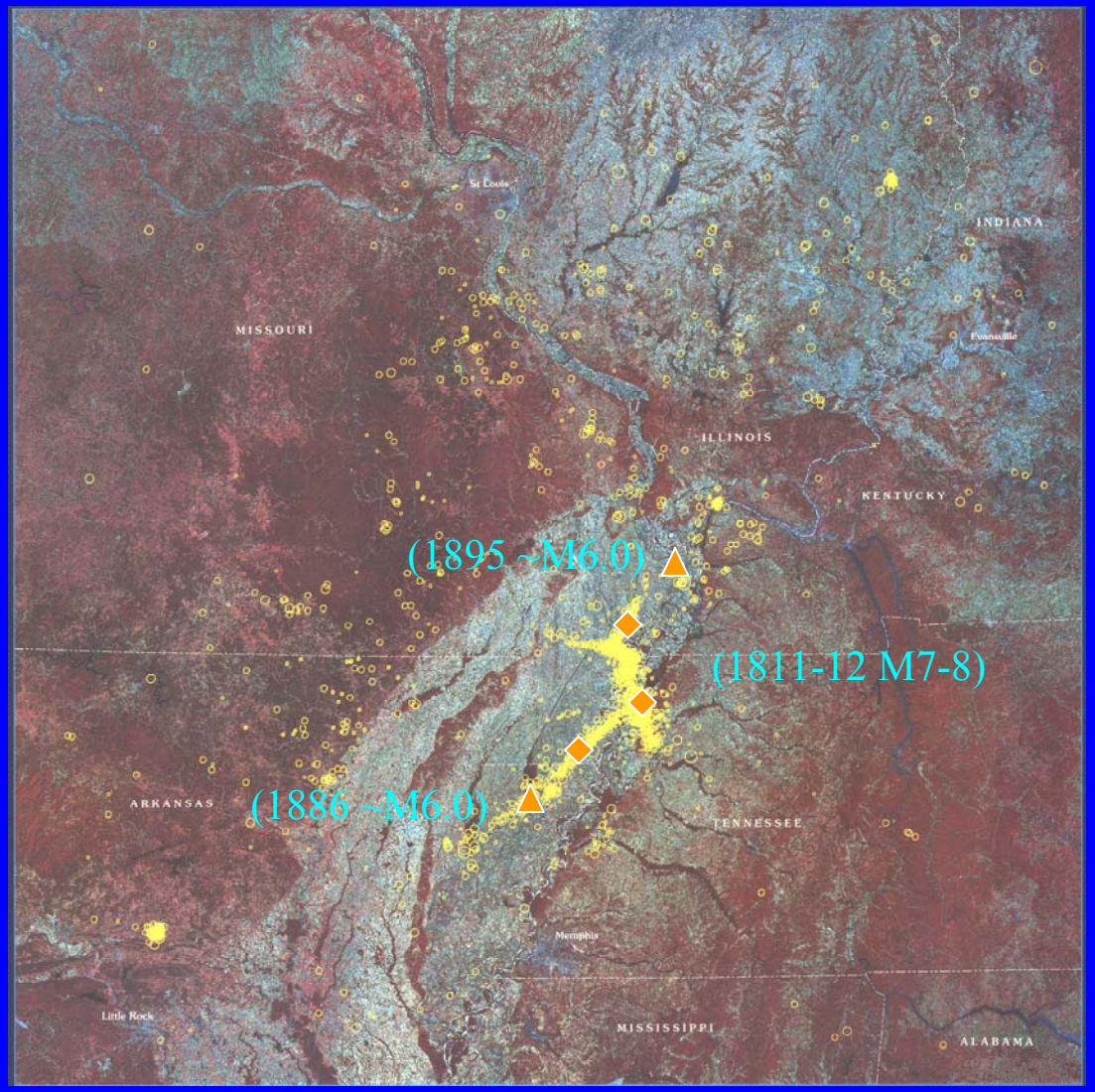
KRCEE – PGDP Technical Symposium

October 30-31, 2007

Final Report: Seismic Hazard Assessment of PGDP

- Completed: June 2007 (six-year effort)
- Peer Review Panel
  - Roy B. Van Arsdale
  - Gail Atkinson
  - James E. Beavers
  - Kenneth W. Campbell
  - Leon Reiter
  - Mai Zhou
- Panel Consensus
  - 1. The ground-motion hazards with a 2,500 return period estimated by the U.S. Geological Survey (Frankel and others, 1996, 2002) are conservative.
  - 2. PSHA, as a methodology, is the common approach for seismic hazard assessment, but some improvements are needed.
  - 3. It is difficult to provide an estimate of seismic hazard for the Paducah Gaseous Diffusion Plant because a reasonable estimate is subjective.

Goal: ground motion with an occurrence frequency



New Madrid Earthquake

1) Magnitude: M7.0-8.0 (how big)

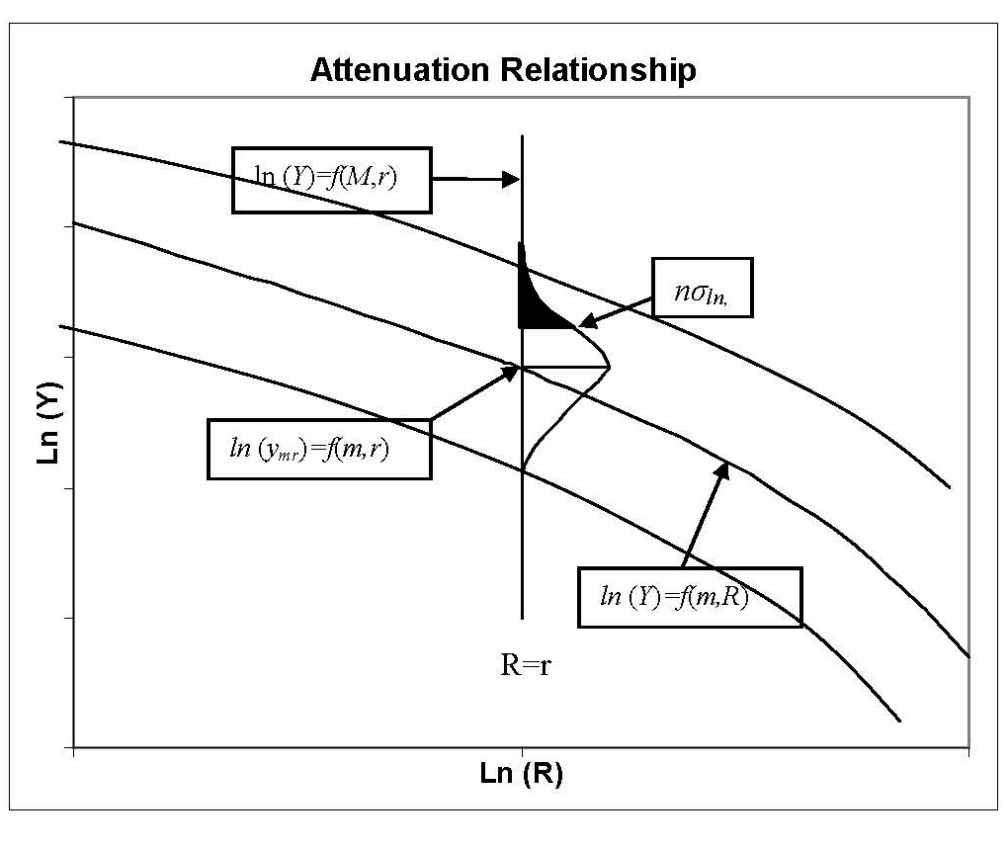
2) Recurrence interval: 500~1,000 years (how often)

3) Location: consistent with current seismicity (where)

4) At PGDP: ~VIII MMI (0.3g PGA) (how strong)

Missing Piece: ground motion attenuation relationship

G-M Attenuation Relationship

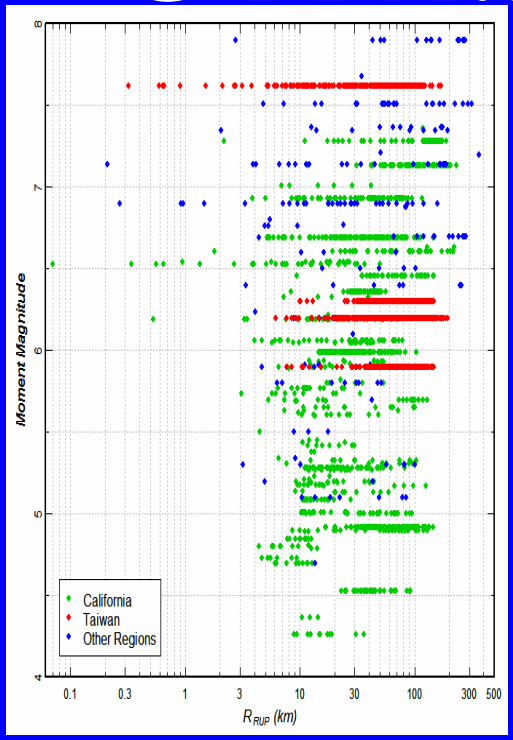


$$\ln(Y) = f(M,R) + n\sigma_{\ln,Y}$$

Median

Uncertainty

G-M Attenuation Relationship



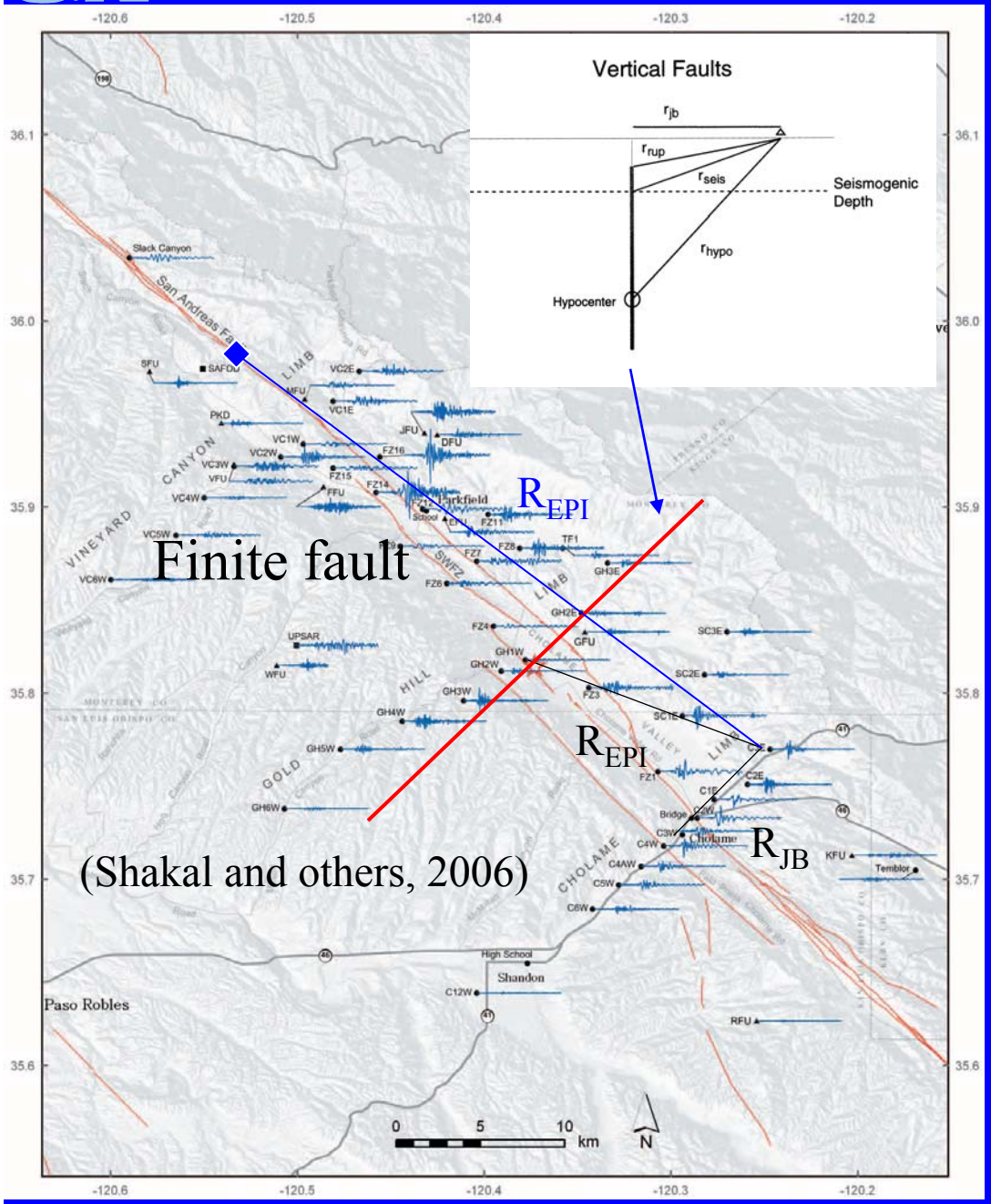
$$\ln(Y) = f(M, R) + n\sigma_{\ln,Y}$$

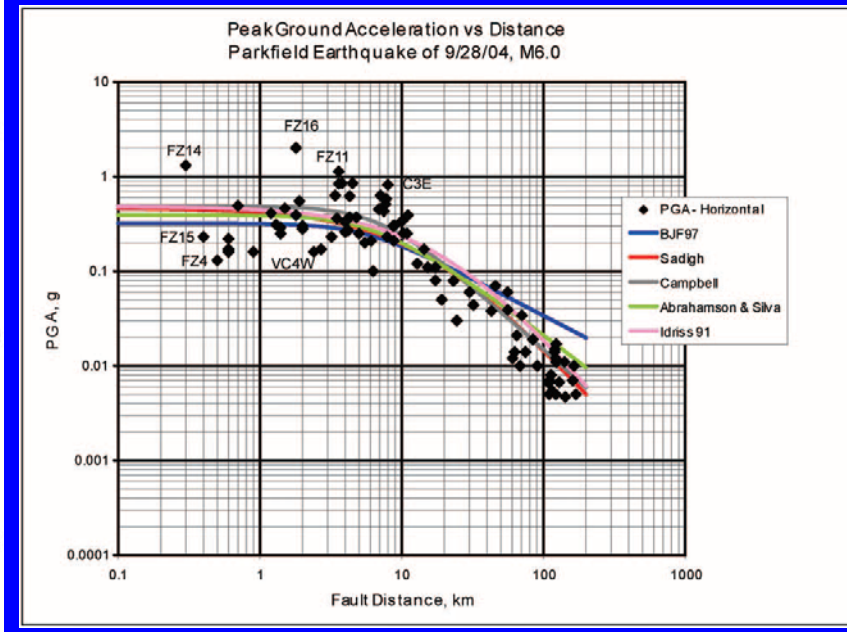
Median

Uncertainty

A spatial relationship,
Not a temporal one

Figure 1: Magnitude-distance-region distribution of selected recordings (Chiou and Youngs, 2006)





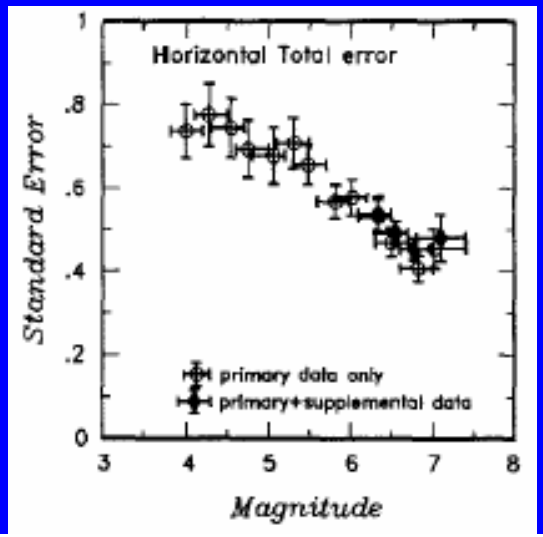
$$\ln(Y) = f(M, R) + n\sigma_{\ln,Y}$$

Dependent on *R*

R is measured as
R_{JB} or R_{RUP}

G-M Attenuation Relationship

104	Coalinga, CA (A17)	09/11/1983	4.5	1	1	1	2
105	Morgan Hill, CA	04/24/1984	6.2	0	7	5	14
106	Bishop, CA	11/23/1984	5.8	0	1	5	4
107	Hollister, CA	01/26/1986	5.4	0	3	2	7
108	N. Palm Spr., CA	07/08/1986	6.1	0	4	0	18
109	Chalf.Val., CA (FS)	07/20/1986	5.9	0	3	1	4
110	Chalf.Val., CA	07/21/1986	6.3	0	4	2	4
111	Chalf.Val., CA (A1)	07/21/1986	5.6	0	1	2	3
112	Chalf.Val., CA (A2)	07/31/1986	5.8	0	0	0	3
113	Cerro Prieto, Mex	11/30/1986	5.4	0	1	0	2
114	Whitt.Nar., CA	10/01/1987	6.0	1	9	3	9
115	Whitt.Nar., CA (A)	10/04/1987	5.3	0	4	1	4
116	Sup.Hills, CA (A)	11/23/1987	6.3	0	1	0	20
117	Sup.Hills, CA (B)	11/24/1987	6.7	0	1	0	29
118	Sup.Hills, CA (B1)	11/27/1987	4.2	0	1	0	0

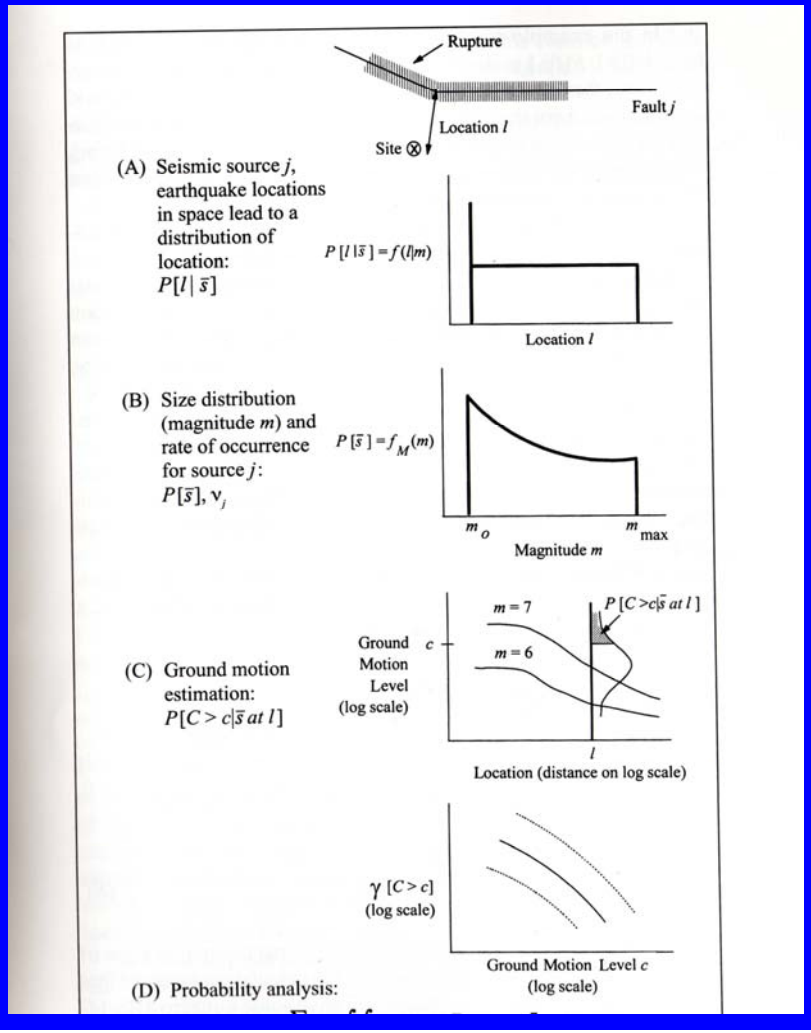


(Youngs and others, 1995)

$$\ln(Y) = f(M, R) + n\sigma_{\ln,Y}$$

Also dependent on M

PSHA – Hazard Calculation



(McGuire, 2004)

$$\gamma(y) = \sum \nu \iint \{1 - \int_0^y \frac{1}{\sqrt{2\pi}\sigma_{\ln,y}} \exp[-\frac{(\ln y - \ln y_{mr})^2}{2\sigma_{\ln,y}^2}] d(\ln y)\} f_M(m) f_R(r) dm dr$$

(Cornell, 1968, 1971; McGuire, 2004)

PSHA – Hazard Calculation

$$\gamma(y) = \sum v \iint \{1 - \int_0^y \frac{1}{\sqrt{2\pi}\sigma_{\ln,y}} \exp[-\frac{(\ln y - \ln y_{mr})^2}{2\sigma_{\ln,y}^2}] d(\ln y)\} f_M(m) f_R(r) dm dr$$

If and only if M, R, and $\sigma_{ln,Y}$ are independent random variable (Benjamin and Cornell, 1970; Mendenhall and others, 1986)

$$\ln(Y) = f(M, R) + n\sigma_{\ln,Y}$$

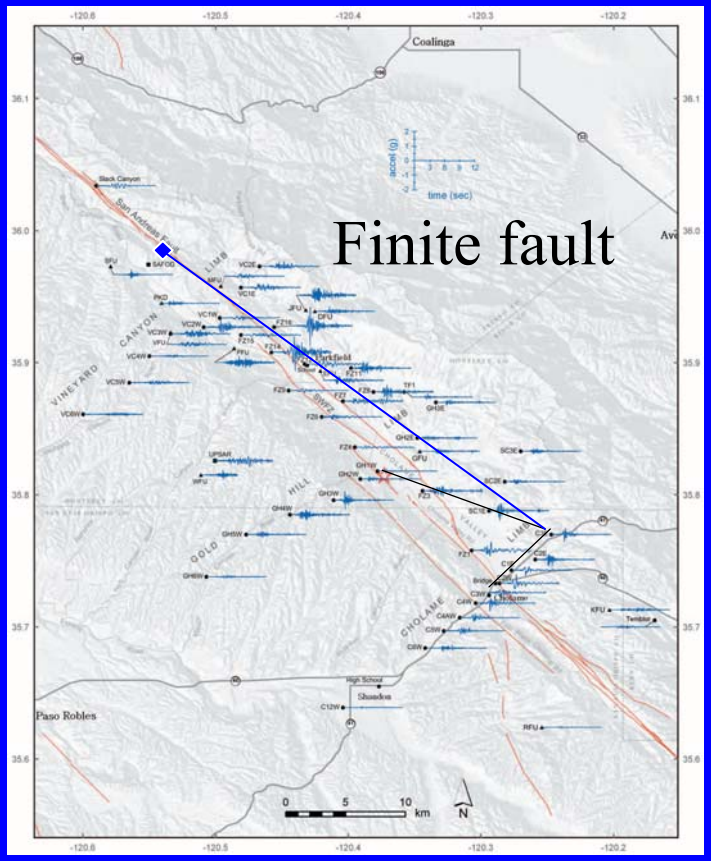
$\sigma_{ln,Y}$ is not an independent random variable, but an explicit or implicit dependence of M, R, *and others*.

Hazard calculation is mathematically incorrect

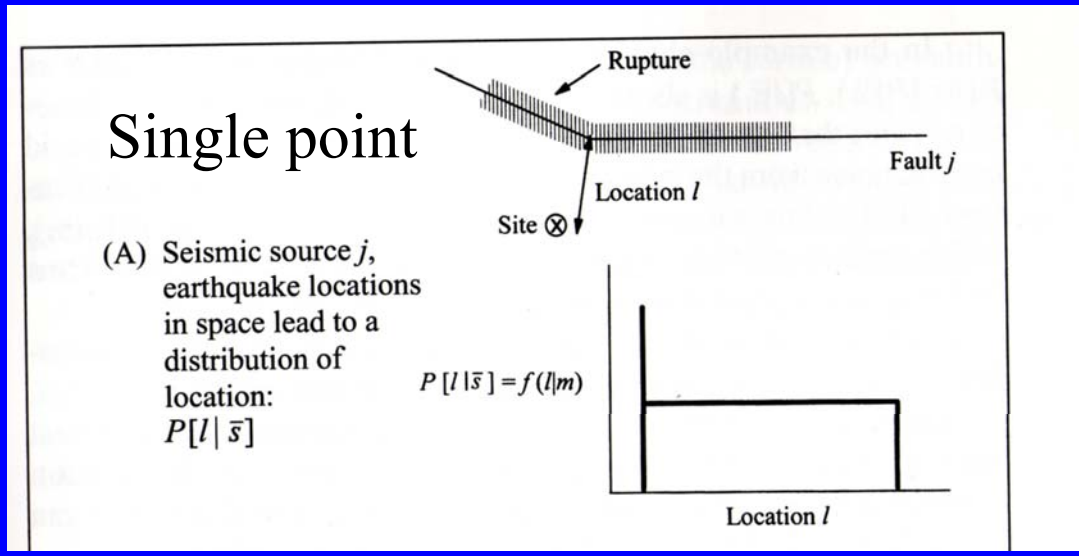
PSHA – Hazard Calculation

$$\gamma(y) = \sum \nu \iint \{1 - \int_0^y \frac{1}{\sqrt{2\pi}\sigma_{\ln,y}} \exp[-\frac{(\ln y - \ln y_{mr})^2}{2\sigma_{\ln,y}^2}] d(\ln y)\} f_M(m) f_R(r) dm dr$$

Uncertainty in R



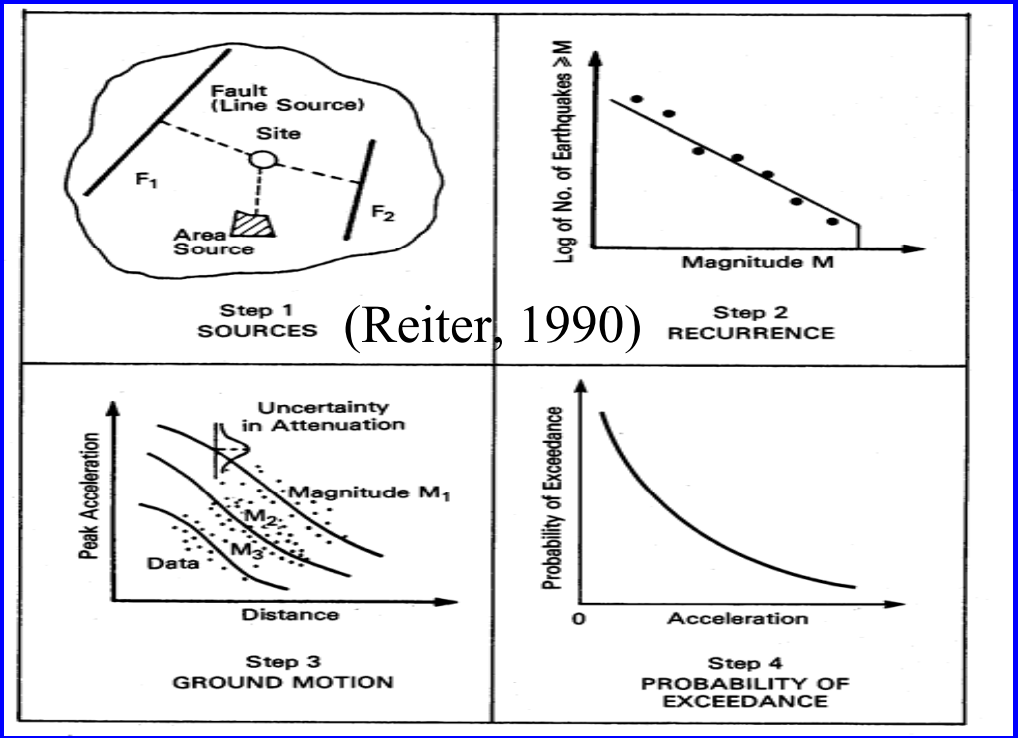
Finite fault



Physical model (single point source) is not valid

PSHA – Hazard Calculation

Source (R)



(Reiter, 1990)

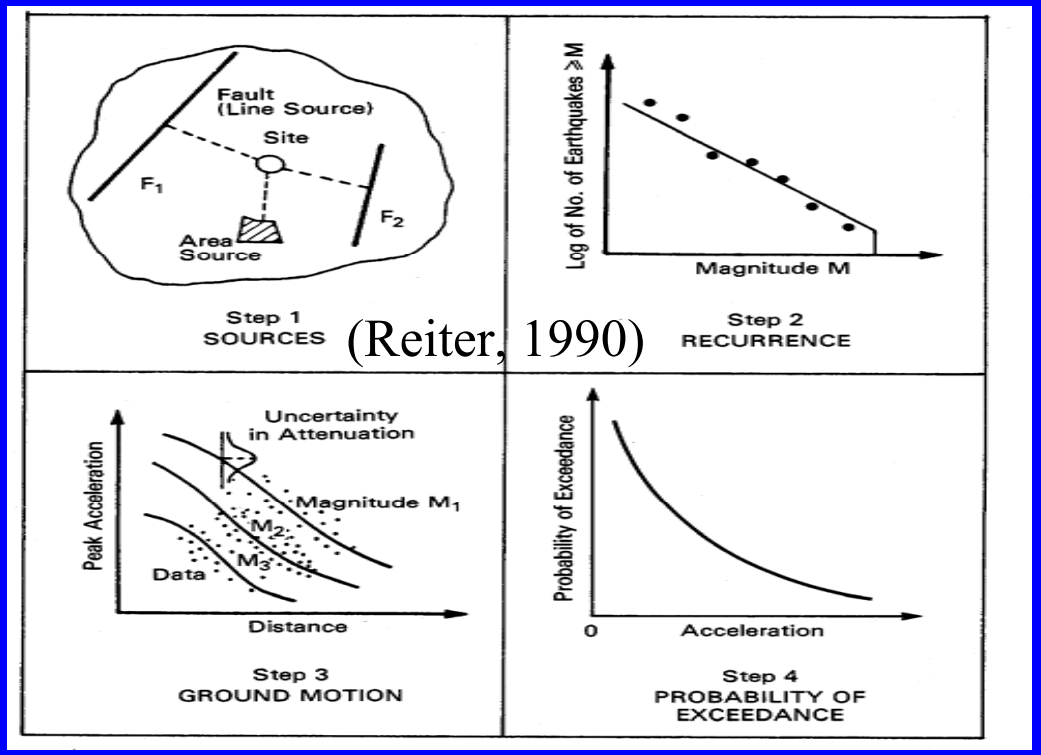
$$\tau = \frac{1}{N} = e^{-2.303a+2.303bM}$$

$$\ln(Y) = f(M,R) + n\sigma_{\ln,Y}$$

$$\gamma(y) = \sum \nu \iint \{1 - \int_0^y \frac{1}{\sqrt{2\pi}\sigma_{\ln,y}} \exp[-\frac{(\ln y - \ln y_{mr})^2}{2\sigma_{\ln,y}^2}] d(\ln y)\} f_M(m) f_R(r) dm dr$$

Seismic Hazard Analysis (SHA)

Source (R)



(Reiter, 1990)

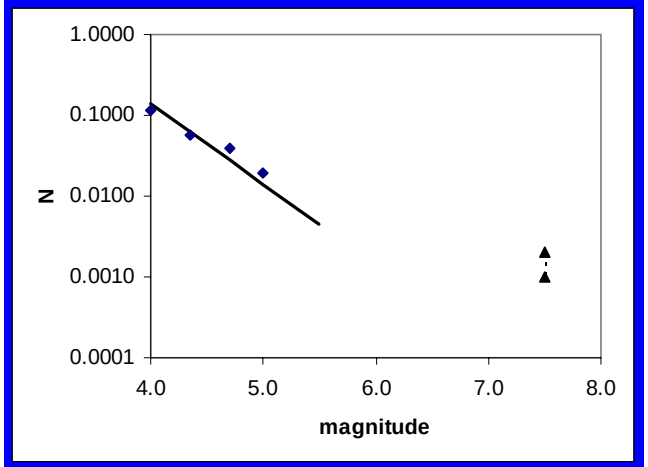
$$\tau = \frac{1}{N} = e^{-2.303a+2.303bM}$$

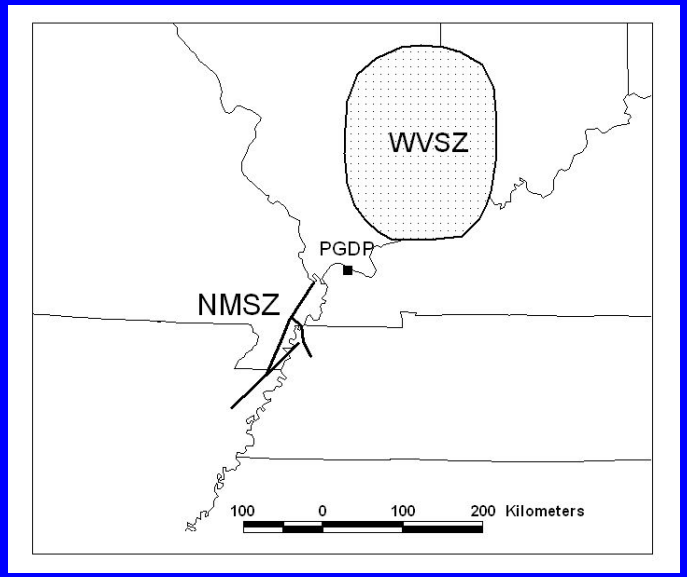
$$\ln(Y) = f(M,R) + n\sigma_{\ln,Y}$$

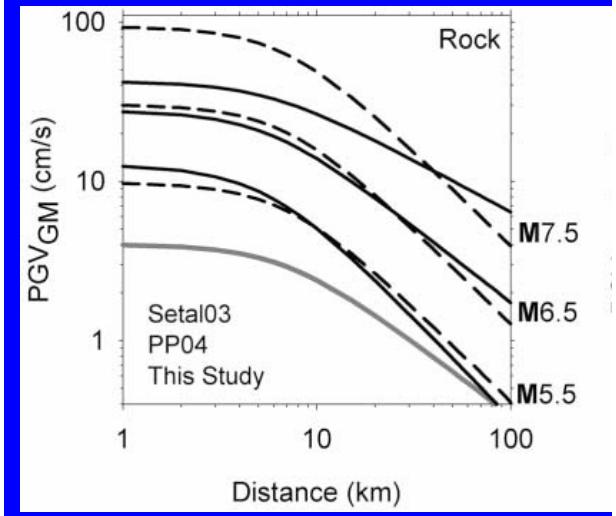
$$M = g(R, \ln Y, n\sigma_{\ln Y})$$

$$\tau = \frac{1}{N} = e^{-2.303a+2.303bg(R,\ln Y,n\sigma_{\ln Y})}$$

SHA for New Madrid Seismic Zone







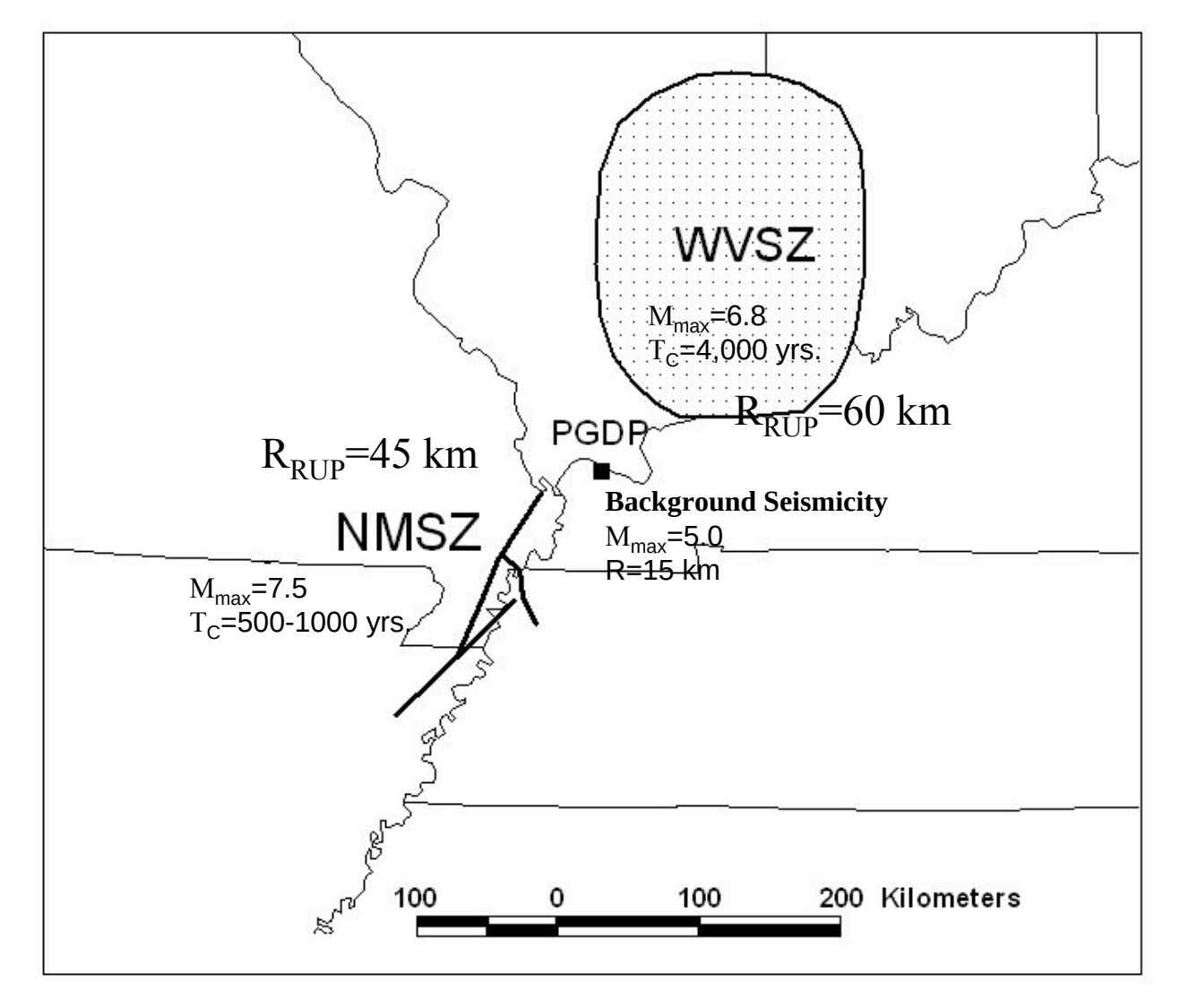
$$\tau = \frac{1}{N} = e^{-2.303a+2.303bM}$$

$$\ln(Y) = f(M,R) + n\sigma_{\ln,Y}$$

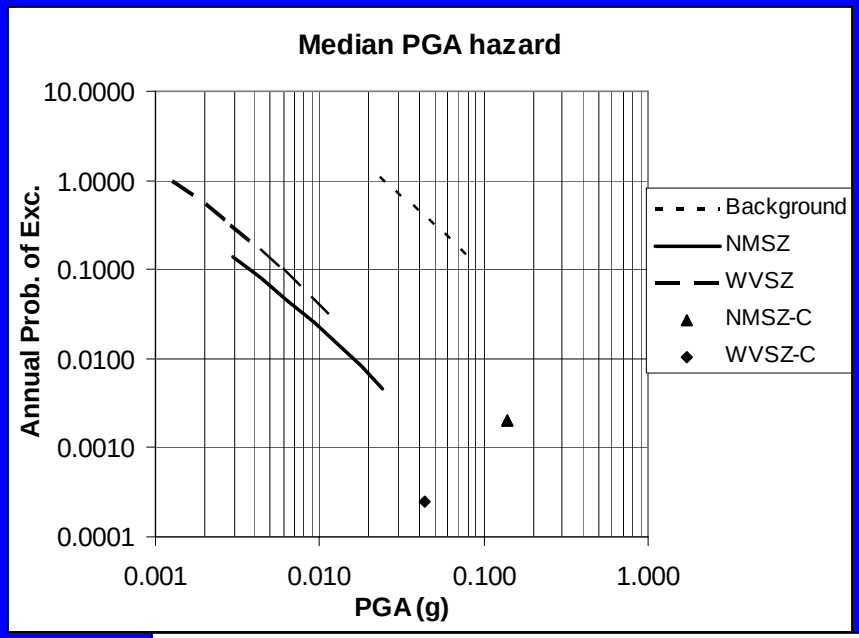
$$M = g(R, \ln Y, n\sigma_{\ln Y})$$

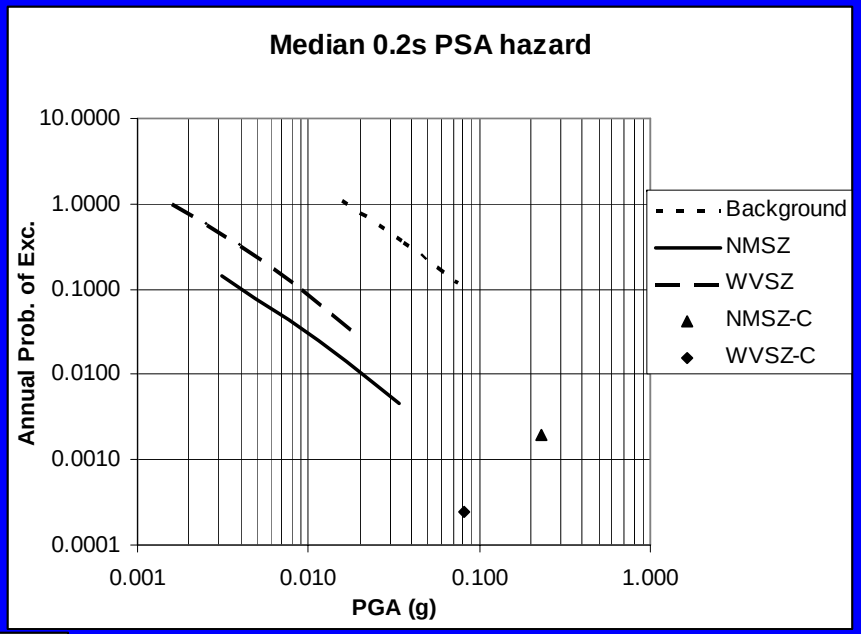
$$\tau = \frac{1}{N} = e^{-2.303a+2.303bg(R,\ln Y,n\sigma_{\ln Y})}$$

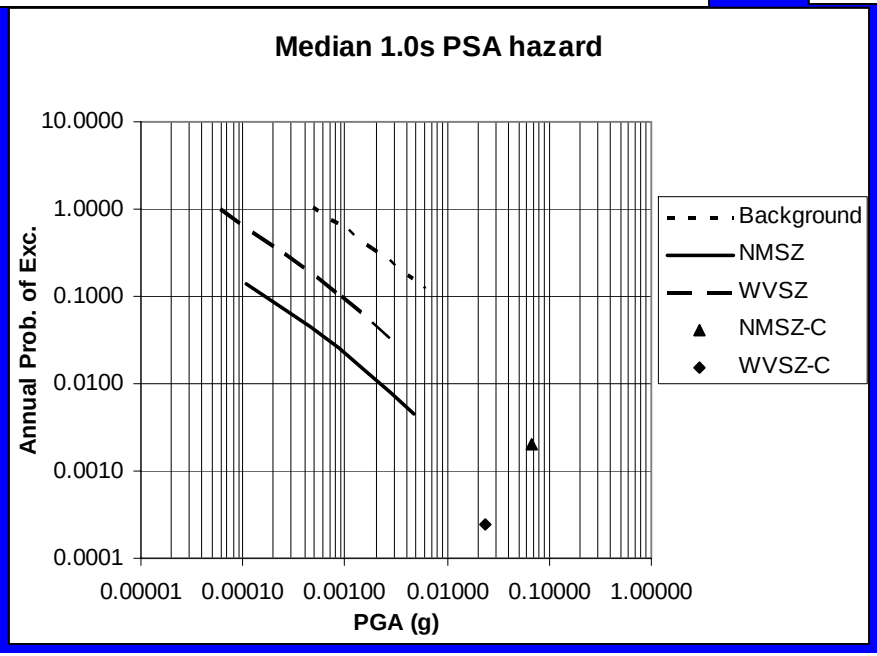
SHA for PGDP


WVSZ
M_{max}=6.8
T_C=4,000 yrs.
R_{RUP}=60 km
PGDP
R_{RUP}=45 km
Background Seismicity
M_{max}=5.0
R=15 km
NMSZ
M_{max}=7.5
T_C=500-1000 yrs
100 0 100 200 Kilometers

SHA for PGDP





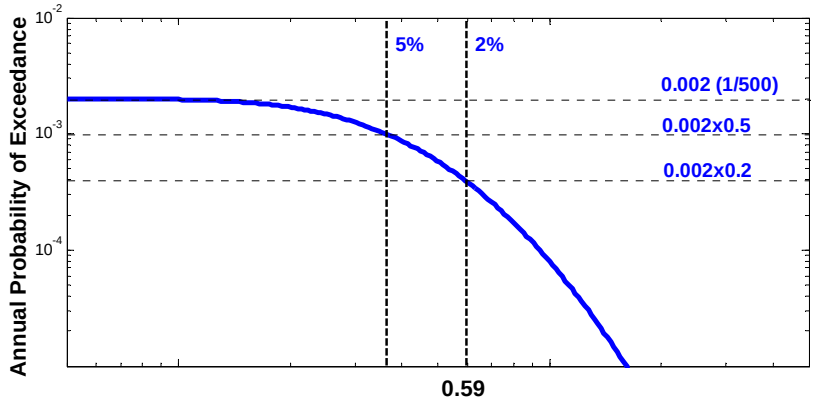


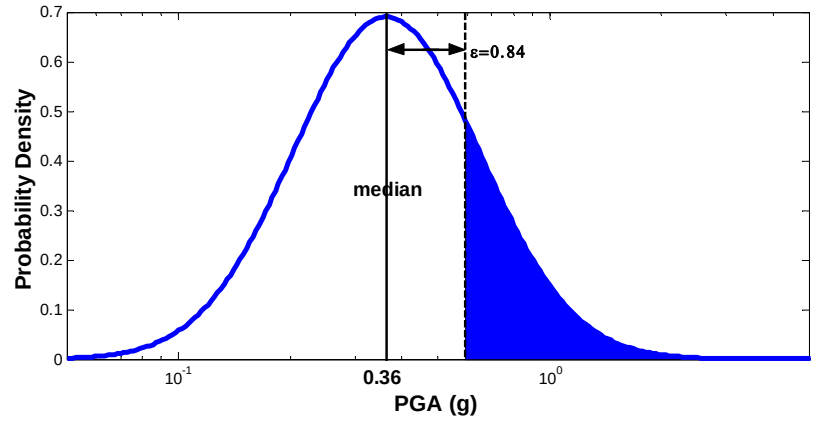
NMSZ controls hazard at PGDP

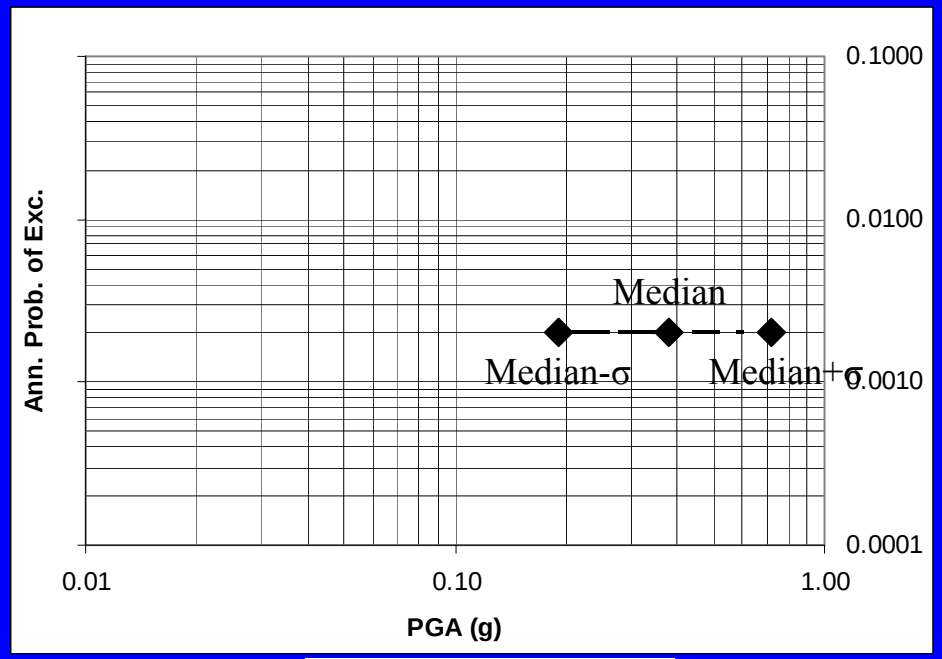
PSHA and SHA Comparison

Single characteristic earthquake m_c~7.5, *T~500 years* in NMSZ

$$T_{RP}(y) = \frac{500}{1 - \int_0^y \frac{1}{\sqrt{2\pi}\sigma_{\ln,c}} \exp\left(-\frac{(\ln y - \ln y_c)^2}{2\sigma_{\ln,c}^2}\right) d(\ln(y))}$$







T_{RP}=500 years

SHA for PGDP

Recommended ground motions on bedrock at the Paducah Gaseous Diffusion Plant

	Average Median (g)	Average Median $+1\sigma_{ln,y}$ (g)	Average Median $+2\sigma_{ln,y}$ (g)	Average 1.5 Median (g)
PGA	0.27	0.50	1.00	0.41
0.2s PSA	0.40	0.80	1.60	0.60
1.0s PSA	0.10	0.20	0.50	0.15

Return period: 500~1,000 years

ACEHR - October 23-24, 2007

- ACEHR – Advisory Committee on Earthquake Hazards Reduction (charged by US Congress)
- At USGS National Earthquake Information Center (NEIC), Golden, CO (also houses the national hazard mapping team)
- Pat Leahy (retired USGS chief geologist) told the committee that "USGS is moving from probabilistic approach to deterministic or physical based approach" for seismic hazard assessment

Thank you